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CONCEPTUAL DESIGN OF AN IMAGE RECORDING SYSTEM FOR THE COMPENSATED IMAGES SYSTEM

University of California

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CONCEPTUAL DESIGN OF AN IMAGE RECORDING SYSTEM FOR THE COMPENSATED IMAGES SYSTEM

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This report describes the conceptual design of an image recording system to replace the present data recording system used in the DARPA/RADC compensated imaging system. The difficulties encountered with the present system are analyzed and a system which will overcome these difficulties is proposed. The system proposed will record in digital form up to 600 512 x 512 images at a rate of one per second. The stored images are available for immediate review and subsequent computer enhancement.

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SUMMARY

This report presents a conceptual design for a new image recording system for use with the Compensated Imaging System (CIS) developed by DARPA/RADC/ITEK. The features of this image recording system are:

1. It uses a standard rate TV camera as a sensor for image data. However, it could also use the present SEVS or CCD camera, if available.

2. Integration for noise reduction is done digitally in real time.

3. The time integrated digitized images are stored directly on computer disk.

4. The throughput rate onto disk is at least one 512 x 512 image per second.

5. Storage capacity of the system is 600 digitized images.

6. A video tape recorder records the raw non-integrated video and allows a replay of the mission to be made at the site or at other locations. This allows redigitization of the data at different integration times to be performed.

7. A video disk allows recording of either time integrated images or real time data.

8. Rapidly rotating images can be recorded with the video tape recorder, then digitized after the mission.

9. Playback of the digitized images can be done immediately after the mission.

10. Real time image enhancement using a 15 x 15 convolving function can be done on either direct video or playback video.

11. Images can be transferred to the CIS executive computer for processing, then returned to the system for display.

12. The system is built mainly from off-the-shelf commercially available hardware.

13. The system maintains hardware and software compatibility with the present CIS computer.

14. Cost estimate for the system is approximately $440,000.

The system does not record wavefront data. The present DRS (Data Recording System) is well adapted for that task.

The design is conceptual. Representative manufacturers were chosen for pricing. If a decision were made to pursue the system, a more detailed investigation would have to be made to determine the actual components to be used and to better estimate the labor and material costs. Very careful attention would have to be given to selection of the camera and other critical components of the system.

The system proposed offers great responsiveness and flexibility in viewing CIS images.

CONCEPTUAL DESIGN OF AN IMAGE RECORDING SYSTEM FOR THE COMPENSATED IMAGING SYSTEM

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REVIEW

The Data Recording System (DRS) for the Compensated Imaging System (CIS) was designed to record video, wavefront and housekeeping data in real time during a mission. A simplified block diagram is shown in Figure 1.

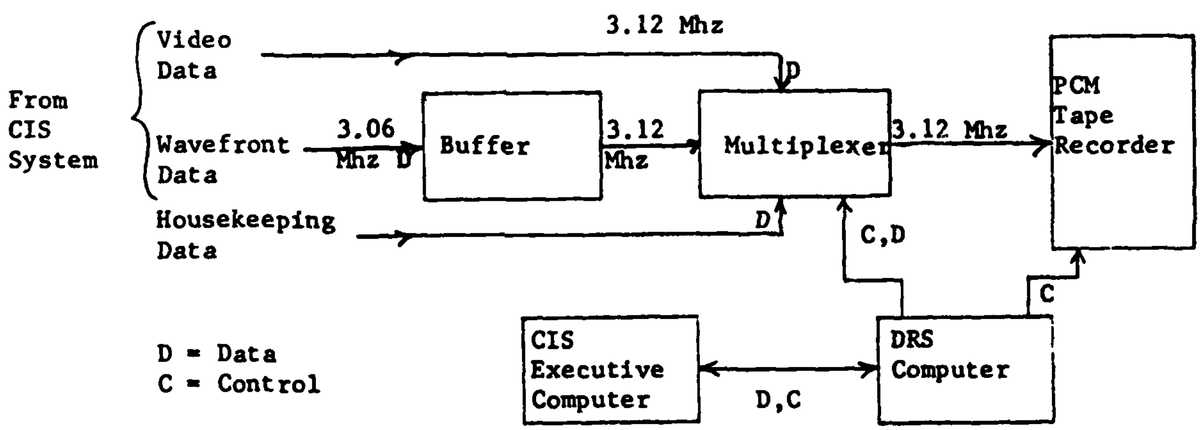


Figure 1 Simplified block diagram of the Data Recording System.

The video data, obtained from the Short Exposure Vidicon System (SEVS) is not continuous but rather comes in bursts at intervals determined by the CIS executive computer. In between these bursts the wavefront data and identification data are recorded. Switching between the inputs is done by the multiplexer under control of the DRS computer.

The video data comes from a special slow scan camera system known as the SEVS (Short Exposure Vidicon System). This system employs a silicon intensified target (SIT) vidicon as a sensor. It can integrate an image from .01 to 10 seconds. This exposure range allows very bright to very dim targets to be recorded.

Following exposure, read out occurs in 1/8 sec. The data is read out in a 560 x 560 square format at a rate of 3.12 megabytes a second. The purpose of recording the video data is to make it available for viewing and enhancement processing after the mission.

The wavefront data consists of phase differences along the image wavefront as measured by the wavefront sensor in the CI system. Differences in both the horizontal and vertical direction are provided. The purpose for recording the phase differences is to provide image degradation information which can be used in image enhancement processing after the mission. The absolute necessity of the phase difference data for image enhancement has not been fully verified at this time. The wavefront data is produced by the CI system at a rate of 3.06 megabytes per second. A buffer converts this to bursts of 3.12 megabytes per second so as to be in synchronism with the tape recorder. Wavefront data is recorded during image exposure.

The tape recorder is a Bell and Howell VR 3700B wide band pulse code modulation (PCM) recorder. It can record a 12 bit word at 3.12×10^6 words per second. In this system only 8 bits are utilized for image data, so the recording rate is 3.12 megabytes per second. Recording is done at a speed of 120 inches per second. For a 7200 foot tape 12 minutes of data can be recorded, representing 2250 megabytes of data. Six seconds are required for the tape to reach operating speed starting from a standstill. Stop time is four seconds.

The CIS executive computer controls the intervals at which image data is recorded on the PCM tape. Through operator controls intervals of 2, 5, 10, and 20 seconds between image recording can be chosen. Manual control is also available.

Once a mission is completed the tape is rewound and data can be read back into the DRS computer. A simplified block diagram of the playback system is shown in Figure 2.

Playback of the DRS data can be divided into two processes: 1) search for the data field and 2) actual reading of the data. During these processes two different tape speeds are used, 120 inches per second (IPS) and 3.75 IPS. The 3.75 IPS is a speed reduction of a factor of 32. This slow down is due to timing considerations in the DRS to HP computer process, which will be analyzed in detail in the next section.

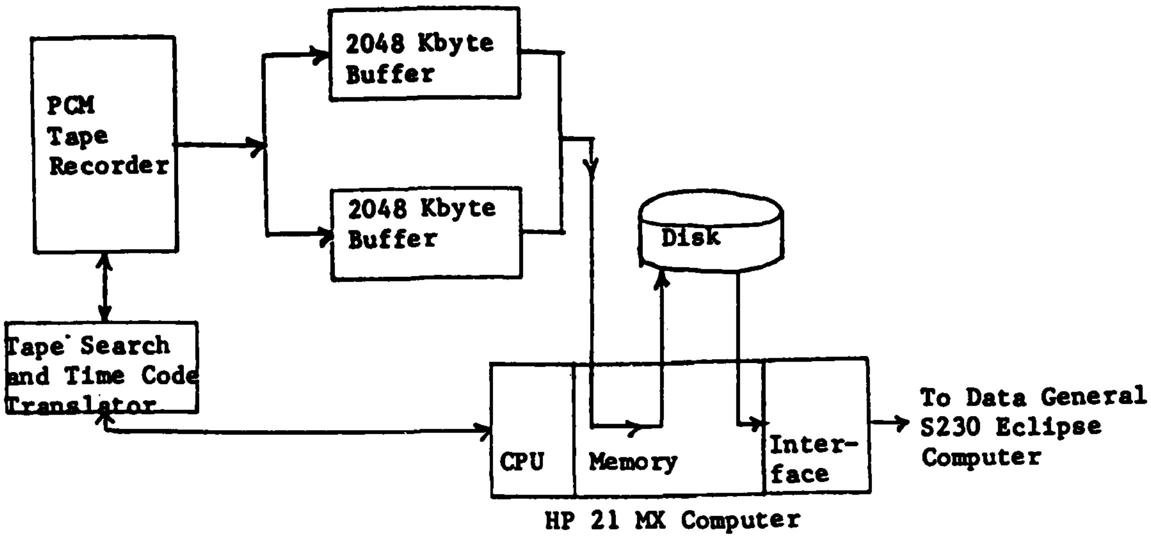


Figure 2 Configuration of the Data Recording System during playback.

The search for the data field consists basically of the following steps.

a) At 120 IPS a search of the time code on the tape is made until the proper time code is found. The length of time required for this depends on how far away from the starting location the desired time code is. It could range from a few seconds to - 10 minutes for a 7200 ft. tape.

b) When the desired time code is passed the tape stops and is rewound past the desired location for about a 50 ft. length of tape.

c) The tape is then moved forward at a tape speed of 3.75 IPS. It takes about 2.7 minutes (for 50 feet) to reach the desired time code again.

d) The tape continues to move without stopping, reading the header data. Next comes the phase data. If it is to be read, then it is, if not then the tape continues to the image data. A 1 second image exposure would require 3.2 seconds to read in the phase data to the HP disk or to ship over. If the image data is to be read it requires about four seconds to read to the HP disk. The actual process is analyzed in detail in the next section.

e) Once an image is read to the HP disk, it must then be transferred to the disk on the system executive computer, the Data General S230. After the transfer commands have been given, the actual disk to disk transfer process takes several minutes.

The time required for the above process for an image that is positioned near the current tape location is, including the time required for operator actions, about 8 minutes for a single image.

ANALYSIS OF PRESENT DRS

Advantages and Disadvantages

The present DRS has several strong features: a high data recording rate of 3.12 megabytes per second and a high data storage capacity of about 2250 megabytes. These combined features can hardly be matched by any other digital data storage technology. If this combination of high data rate and high capacity remains a requirement, then the present system meets that need. An additional advantage of the present DRS is that it is a complete integrated functioning system.

The present DRS system has several significant limitations. One is the slow playback speed. The system searches for a time code at high speed, stops, backs up, and then plays back at a slow speed, 1/32 of the original speed. The entire process takes at least 8 minutes to recover a single image and its associated wavefront data. Another limitation is the six seconds required for starting and four seconds required for stopping the tape. This discourages starting and stopping the tape during image recording to capture the data at selected times.

Timing Analysis of the DRS During Playback

The PCM tape recorder has the ability to play back data at rates much faster than is presently used in the DRS. In fact, it can play back at the same rate as it records. The slow playback is imposed by the data rate capability of the computer system used to transfer the data on disk. A brief analysis of the system will indicate the problem.

The Hewlett Packard disk system used has a raw data rate of 937.5 kilobytes per second. This is the data rate when data is actually flowing to the disk. The throughput rate from the DRS tape to the disk, however, is only 97.5 kilobytes per second. Thus, the throughput rate is about 1/10 of the raw data rate of the disk. The loss is due to overhead.

Data from the PCM tape recorder flows alternately into two 2048 byte ping pong buffers and then into the HP computer memory. Figure 3 illustrates this in somewhat more detail than Figure 2.

There is memory allocated for six buffer amounts. A direct memory access (DMA) request starts data flowing into the top half of the memory and continues until A_1, B_1, A_2 have entered. At this point a disk transfer is initiated to move this data to disk. After the disk process is started, another DMA process is started, with B_2, A_3, B_3 now flowing into the bottom half of the memory. At the conclusion of that transfer into memory from the ping pong buffers, transfer of that data to disk is initiated. This completes a cycle and the incoming data is now directed back to the top section of the memory.

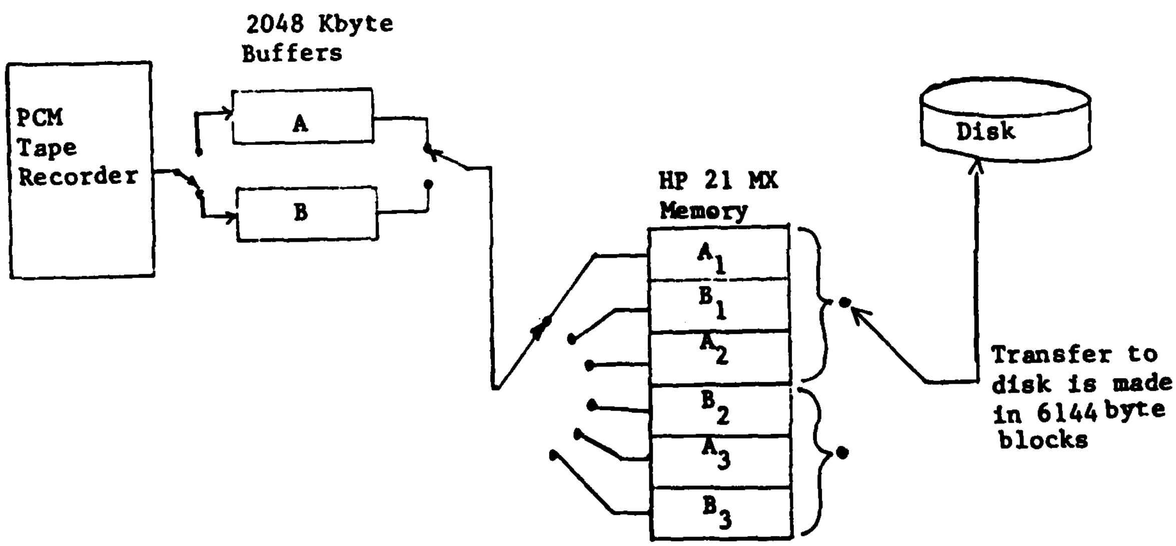


Figure 3 Multiplexing of data during playback

The time budget for the transfer of data to the disk is as follows:

T_{rot}, Rotational delay (time for 1 rev of the disk) = 16.67ms max

T_{seek}, Track to track seek time = 5.0 ms

T_{tran}, Time to transfer 3 x 2048 bytes

$= 6144/937.5 \times 10^3$ = 6.55 ms

T_{prog}, Program time to initiate transfers (guess) = 1.00

29.22 ms

The rotational delay is based on the assumption that the data is laid out continuously on disk sector by sector. Whenever a transfer stops, then a full revolution of the disk must be made before the next transfer can be started, picking up where the last one left off. The track to track seek time will occur whenever one track is full and the head has to move to a new track. This will not occur on each transfer but must be included. The transfer time is the time required to flow N_{bytes} of data onto disk at the intrinsic transfer rate of R_{trans}. The program time is the time required to initiate the DMA transfer and disk transfer. The throughput rate R_{thru} is

$$R_{thru} = \frac{N_{bytes}}{T_{rot} \quad u \quad T_{seek} \quad T_{prog} \quad N_{bytes} \quad R_{trans}}$$

For this case R_{thru} = 6144/.0292 = 210 kilobytes per second. For various tape speeds the data rates from the DRS are:

PCM Tape Speed (IPS)	120	60	30	15	7.5	3.75
Data Rate (KBS)	3120	1560	780	390	195	97.5

Thus, a PCM tape speed of 7.5 inches per second with a corresponding data rate of 195 kilobytes per second appears to be consistent with the potential throughput rate of 210 kilobytes per second of the computer. Apparently there are other overhead factors not accounted for or a safety factor was needed, so that the designers of the system chose a tape speed of 3.75 inches per second, resulting in a throughput rate of 97.5 kilobytes per

second.

Speeding up the DRS Rate

Looking at the equation for the throughput rate, we see that R_{thru} can be made larger by increasing N_{bytes} or by decreasing T_{rot}, T_{seek}, or T_{prog}. Increasing N_{bytes} could be accomplished by utilizing more computer memory so that a larger amount can be transferred at one time. A possible scenario would be as follows: 1) Fill a track completely with data except for a few sectors (of the 48 sectors per track) to allow head switching over the three disk surfaces within a disk cylinder. 2) Switch between tracks while the heads are over the non-used sectors. 3) Continue data transfer until all three tracks of the cylinder are full. All of this would be done without any intervening head seeks or lost disk rotations. Assuming two of the 48 sectors are given up for head switching, giving .69ms for head switching, the number of bytes that would be transferred is

$$N_{bytes} = 46 \text{ sectors/track} \times 256 \text{ bytes/sector} \times 3 \text{ tracks/cylinder}$$
$$= 35.33 \quad \text{kilobytes/cylinder}$$

The throughput rate would then be

$$R_{thru} = (35.33 \times 10^3) / (16.67 \quad 5 \quad 1)10^{-3} \quad 35.33 \times 10^3 / 937.5 \times 10^3)$$
$$= 585.4 \text{ kilobytes per second}$$

The nearest PCM tape speed with a rate lower than this would be 15 inches per second (with corresponding data rate of 390 kilobytes/sec). This would be a factor of four speed up in tape speed over the present system. It would require 2 x 35.33 = 70.66 kilobytes of computer memory whereas the present system is using only 6 x 2048 = 12.29 kilobytes of memory. The computer system has a total of 128 KB of memory. How much is available for additional storage is not known. The HP 21MX is capable of supporting at least 512 kilobytes of memory, so that more could be purchased if necessary. An other unknown is whether the ping pong buffers could keep up with the faster rate.

To summarize, it appears that by careful tuning of disk formating and software a factor of 4 speed up of the DRS could be achieved, assuming computer memory for the HP 21 MX computer is available and that the ping pong buffers can work at the faster

rate.

CRITERIA FOR A NEW IMAGE RECORDING SYSTEM

DRS to System Executive Transfer Rate

Another bottleneck appears to be the time required to transfer from the HP 21MX disk to the Data General SL30 disk. While exact timing is not available, several minutes are required for this transfer. The transfer rate apparently is below 500 bytes/second. This is several orders of magnitude below the new transfer rates of the disks involved.

SEVS Problems

The present SEVS camera suffers from several deficiencies, the most serious of which is excess video noise due to electromagnetic interference (EMI) and preamplifier noise. The EMI noise has been found to be primarily generated within the camera itself and, due to unconventional design, will be difficult to correct. A brief analysis of these noise components is given in Appendix A.

General Criteria

The primary difficulties with the present DRS are extremely slow playback, and long start and stop times. A new system without these deficiencies would be desirable. Several criteria for a new system are:

1) Ability to rapidly review images after a mission.

2) Ability to transfer the images to the CI executive computer for post detection processing.

3) Use of off-the-shelf systems and components to avoid a long development time.

Reduction of Data Rates and Capacity

Some compromise with respect to data recording rate and capacity will have to be made in order to develop a system which meets these criteria. It appears that with existing commercially available technology the PCM recorder is the cost effective choice <u>if</u> a high data rate of 3.12 bytes/second and capacity of over a billion bytes is required. If, however, both the recording rate and the storage capacity can be decreased then the criteria can be met with other components.

A major step towards reducing the data recording rate and storage capacity for image data would be to separate the image and wavefront data recording, using a separate recording system for image data and a separate recording system for wavefront data. This seems logical because the need for immediate review of wavefront data after a pass is much less than for image data. The wavefront data is needed only for a specific type of post detection processing and rapid retrieval may not be necessary. Additionally, the need for the wavefront data in post detection processing has not yet been firmly established. Experience may show that it is not needed for image enhancement, and that its primary usefulness will be for system and atmosphere diagnostic purposes.

Since the wavefront data does occur at a high continuous rate, the present DRS may be the ideal recording system for it.

Image data, on the other hand, needs to be accessible after a mission. Preliminary information extraction about the object. application of rapid enhancement techniques, and analysis of system performance are reasons for this need.

The throughput rate for image data is much lower than the present DRS recording rate of 3.12 megabytes per second. For example the present system reads out a 560 x 560 image at intervals of 2 seconds or more. This corresponds to a maximum throughput rate for image data of only 156.800 bytes per second nearly a factor of 20 below the recording rate of the PCM recorder. Thus, by proper buffering the recording rate for image data could be lowered considerably.

For the sake of analysis, the assumption will be made that an acceptable image recording system would be one which records a 512 x 512 image at a rate of one per second for a period of 10 minutes. This results in

Recording rate = 262,144 bytes/second

Number of images = 600

Recording capacity = 157 megabytes

These appear to be achievable specifications. Ways of achieving these rates and capacities will be discussed later.

Camera Considerations

The present SEVS camera system allows exposure times of .01 to 1 seconds. The longer exposure times are a requirement for dim

targets and high atmospheric turbulence conditions. During long exposures the image is integrated on the target of the SIT tube (an RCA 4804).

An important requirement for the camera system is that the noise in the image be nearly that due to photon noise. This means that the read out of the charge pattern of the image on the target of the camera tube should add little noise compared to the pattern of noise caused by shot noise in the electron image at the photocathode. This is one reason why dim images must be allowed to integrate so that the signal level at the target is high with respect to readout induced noise.

An alternate method of accomplishing the task of obtaining near-shot noise performance is to increase the gain in the camera tube, take sorter exposures, read out the image more frequently, and average images digitally prior to storage. The gain is made high enough that the noise in the image due to photon shot noise is larger than the read out noise. Long term integration of the shot noise is done digitally in external electronics rather than on the camera tube target.

The primary advantage of using the camera-external integration technique is that it allows standard commercially available camera systems to be used as a sensor. This opens up a broad spectrum of different camera types and manufacturers from which to made a selection. As new advanced cameras are developed and made available. they can be used, without the cost of development being paid by the project as occurs when a specially designed camera system is processed.

The new image recording system to be discussed here will initially be based on the use of camera systems which use standard rate TV cameras. However, a CCD type camera can easily be interfaced to the system. Likewise the present SEVS camera could also be interfaced.

PROPOSED IMAGE RECORDING SYSTEM

To be presented here will be a conceptual design. Commercially available components which appear to have the potential for doing the job will be indicated. Selection of actual components cannot be done until a detailed analysis of requirements and characteristics can be made.

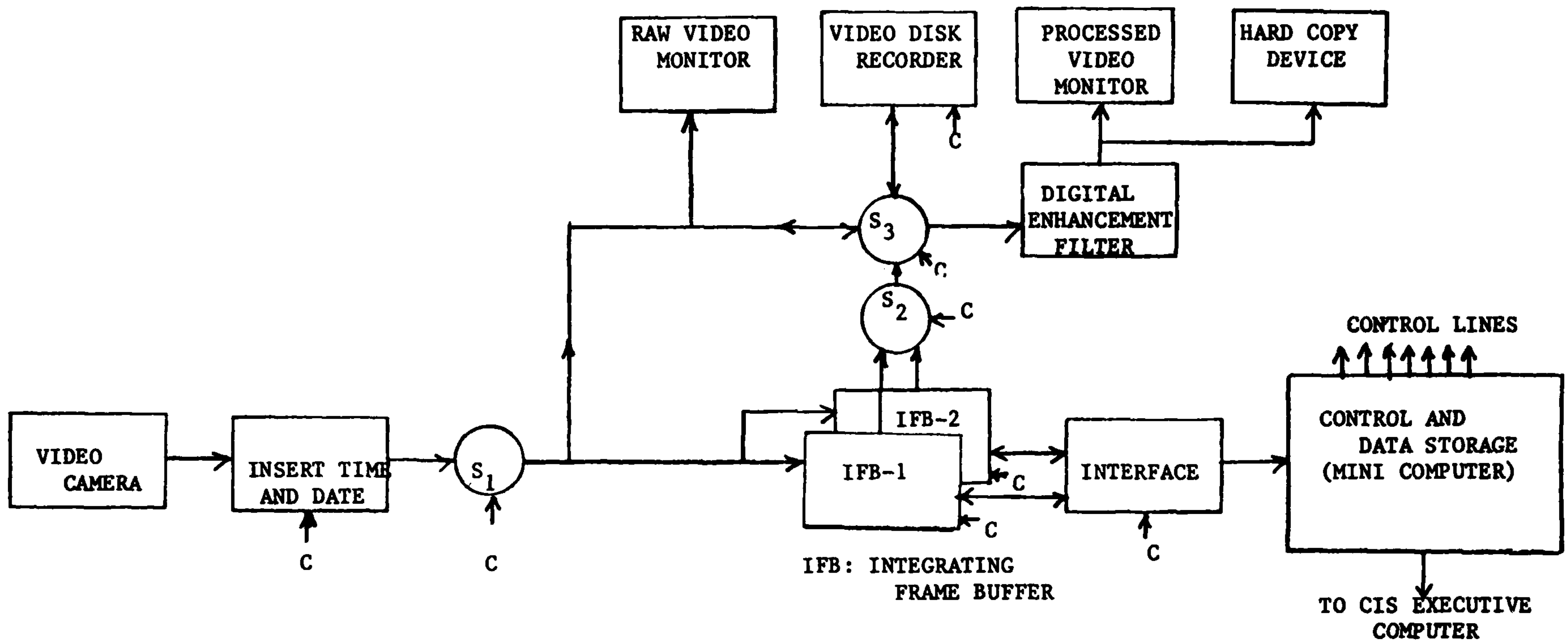
The simplified block diagram for the image system is shown in Fig. 4. The switch settings for the various modes of operation are shown in Fig. 5.

The image recording rate for this system will be required to be at least one 512 x 512 image per second for a time period of 10 minutes. Again this requires:

Throughput rate	= 262,144 bytes/sec
Image storage capacity	= 600 images
	= 157 megabytes,

assuming 8 bits per pixel. Achieving this throughput rate will be one of the major design challenges of the system. While the rate is well below the intrinsic transfer rate of most disk systems, achieving a sustained rate this high requires careful attention to file layout on the disk and careful programming.

This system would have several modes of operation as will be described: standard recording mode, fast image recording mode, playback mode. Changing from one mode to another would be accomplished by changing signal and control switch settings. These changes would for the most part be done under control of the computer.



S denotes a switch. S_2 toggles at integrated frame rate. All lines shown are data except those denoted by C, which are control.

FIGURE 4. BLOCK DIAGRAM OF THE IMAGE RECORDING SYSTEM

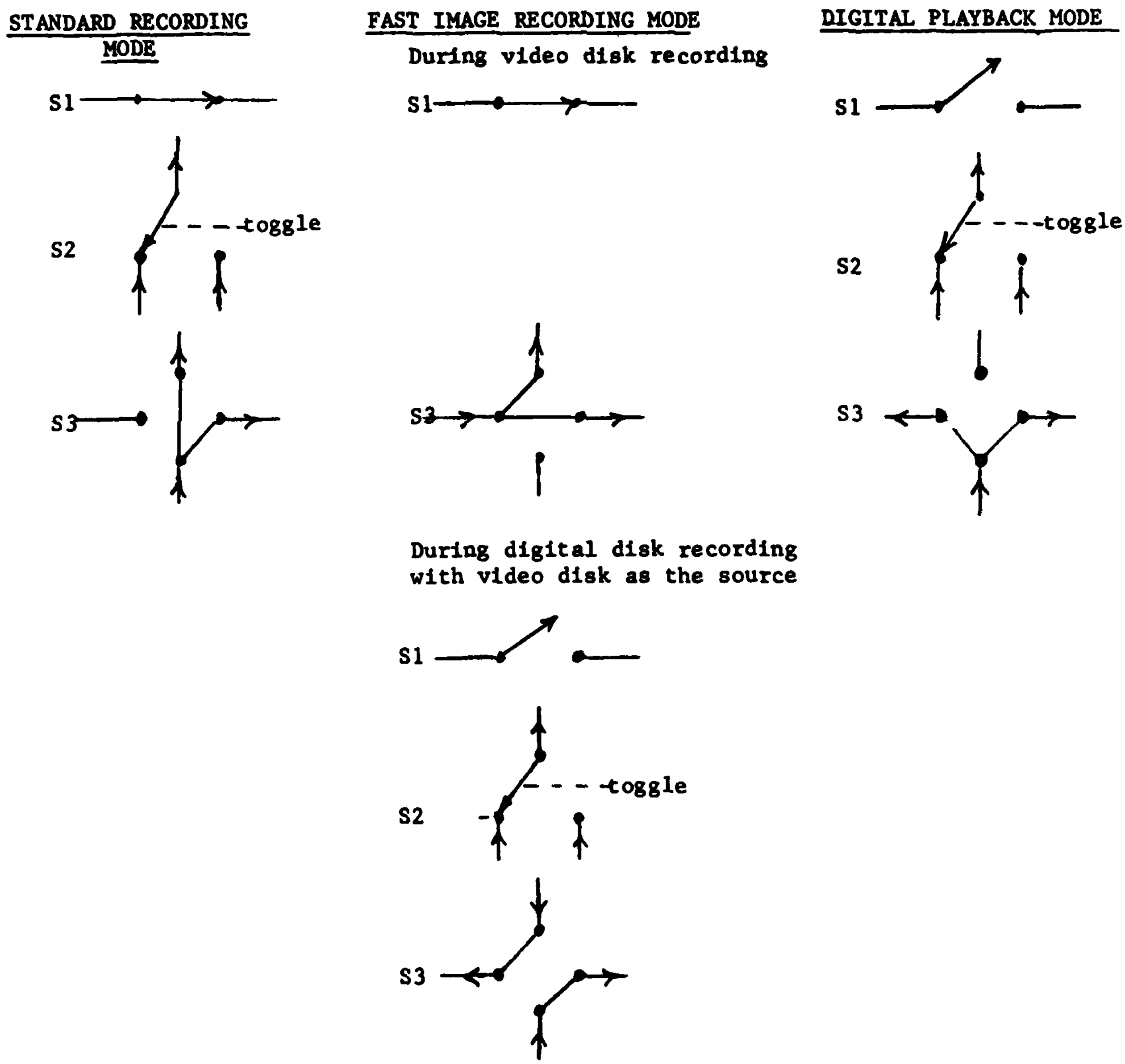


FIGURE 5 SWITCH SETTINGS FOR VARIOUS MODES

Standard Recording Mode

1. The video camera provides continuous analog video. Date and time of day is inserted into this video for ID purposes. This raw video signal is displayed on a monitor so that an operator can make adjustments.

2. An integrating frame buffer digitizes each frame of data and averages N frames.

3. At the end of integration, the signal is transferred to another integrating frame buffer which starts integrating. In the meantime the first buffer begins unloading to the digital disk recording system. The integrated video from the first buffer is displayed on another monitor. If desired this video data can be enhanced by a unit that convolves the 512 x 512 image with a 15 x 15 kernel in real time.

4. This ping-pong process continues until all images are recorded.

5. A video disk recorder is simultaneously recording the integrated data in analog form.

6. A video tape recorder is simultaneously recording the raw data in analog form.

Fast Image Recording Mode

This mode is used when the object is rotating rapidly so that no integration can take place. In this case the system is configured so that the video data goes directly to the video disk and tape recorders. After the pass, the configuration is changed so that the video can be played back from either recorder into the integrating frame buffers which are now used to digitize the image. The digitized data is then stored in the digital disk storage system as before.

Playback Mode

For a rapid review of the non-integrated images the video tape recorder can be rewound and played. If the incorrect integration time was used in the integrating frame buffers, the video tape recorder can be used as a source to replay the raw video back into the integrating frame buffers, essentially allowing the misson to be replayed at a later time.

For rapid exploratory review of the integrated images recorded during the mission, the video disk recorder can be used. This recorder allows any image to be rapidly accessed and displayed or the entire set of images can be stepped through at a selected rate. Enhancement can be applied to the images by use of the 15 x 15 kernel convolving digital filter. The two monitors allow comparison of the enhanced and unenhanced images.

The digital data on disk is viewed by transferring images from disk back into the integrating buffers, which are then used as refresh memories. The following processing can be accomplished rapidly and immediately displayed.

1. Further integration of N frames.

2. Compute difference between images A and B.

3. Compute derivatives (first differences) of an image.

4. Convolve with a 15 x 15 kernel which provides locally adjusted contrast enhancement.

The hard copy device allows any of the video signals from the integrating frame buffer or the video disk recorder to be photographed. Media available for recording are 8 x 10, 4 x 5 instant Polaroid, and conventional 35 mm and 16 mm film.

The digital disk recording system also has a port through which the digital image data can be transferred to the CIS executive computer for more sophisticated processing. Following this processing the data can be transferred back to the image recording system where the additional processing, display, and hard copy capabilities can be utilized.

The various components of the system will now be discussed from the standpoint of cost and availability.

Video Camera

As stated previously, the camera to be used will be a standard format, i.e. 2:1 interlace, 60 or 50 frames per second. There are a variety of commercially available systems as potential candidates. Choice of the best system would require careful analysis of flux ranges to be covered, blooming characteristics, linearity, uniformity, gains available, noise characteristics, image format, and camera size and weight. The most probable cameras are those that would use the following sensor tubes: SIT (silicon intensified target) ISIT (intensified SIT), SEC (secondary emission conduction), ISEC (intensified

SEC), Isocon, and intensified Isocon. Some manufacturers and their prices are listed below. These prices include the control unit but no lens.

RCA

SIT Camera, model TC1030, self contained, 16 mm image format. $6650.

ISIT camera, model TC1040, self contained, 16mm image format. $8800.

COHU

SIT camera, model 4410/SIT, self contained, 16 mm image format. $6300.

ISIT camera, model 4410/ISIT, self contained, 16 mm image format. $10,400.

Isocon camera, model 7302A, separate control unit, 25 mm image format.* $44,000.

Intensified camera, model 7304A, separate control unit, 25 mm image format. $47,000.

SCANCO, INC.

ISIT camera, model QX-26, separate control unit, 16 mm image format. $16,500.

ISIT camera, model SC-25I, separate control unit, 25 mm image format.* $26,000.

ISIT camera, model SC-401, separate control unit, 40 mm image format.* $29,600.

ISEC camera, model SC-25S, separate control unit, 25 mm image format.* $32,500. ISEC camera, model SC-40S, separate control unit, 40 mm image format.* $36,100.

Most of these camera are available with either 30 frames per second, 525 lines, or 25 frames per second, 625 lines. Those marked with an asterisk would require modification of the optics because of a larger faceplate.

The present SEVS camera uses a sensor with a 16 mm format. Any other format would require a modification of the CIS precompensator optics. This might be a non-trivial task.

Time does not permit a detailed camera analysis at this time. Thus, the most expensive camera will be chosen for the analysis so as to provide an upper limit on cost. This value is $47,000.

Time and Date Inserter

One manufacturer has been found for the time and date inserter hardware although others exist. This is the HEI model 508 Video Character Generator. The cost of the unit including necessary options is estimated to be around $5000.

Integrating Frame Buffers

The integrating frame buffers digitize the incoming video data in real time, storing an entire 512 x 512 in solid state memory. For signal to noise reduction multiple frames can be averaged together. After averaging the digital data it is then transferred to disk. Two frame buffers are used so that one can be averaging while the other unloads to disk. At least two sources of frame buffers exist, Quantex and Hamamatsu.

QUANTEX

Quantex digital video processors digitize the data to 8 bits and uses 12 bit for storage. The digitized data can be read out at a maximum rate of 625 x 10^3 pixels per second, or 2.38 images per second. Thus, the goal of obtaining one image per second should be readily attainable. The processors also convert the digitized data back to analog video form for display on a monitor. The processors contain the ability to perform various enhancement operations on the digitized image. These are tabulated in the table below.

Model #	DS-20A	DS-30A	DS-50
Sum images	Yes	Yes	Yes
Average images	Yes	Yes	Yes

Difference images	Yes	Yes	Yes
Edge enhancement	No	Yes	Yes
Contour enhancement	No	Yes	Yes
Window enhancement	No	Yes	Yes
Input A/D controls	Yes	Yes	Yes
Output transform	Yes	Yes	Yes
Memory quartering	Yes	Yes	No
Digital I/O interface	Yes	Yes	Yes
Cost of processor	34,000	39,000	27,500
Cost of interface	2,500	2,500	2,000

Difference images are formed by differencing the present image and the incoming image. This would be useful during playback. Edge enhancement is performed by differencing adjacent pixels in x and y for the stored image. Contour enhancement consist of setting a specified range of gray levels to maximum and all others to zero. Window enhancement consists of setting every value below a specified level to zero and every value above that level to maximum. Input controls allow the upper and lower levels of the video signal for digitization to be specified. Output transform allows a non-linear transformation to be applied to the output data. Memory quartering allows 4 256 x 256 images to be stored in the processor. The digital I/O interface allows connection to a IEEE standard bus.

HAMAMATSU

The Hamamatsu C1440 Video Frame Memory has the following characteristics.

512 x 512 memory

Digitizes video to 8 bits, stores in 16 bit memory

Sums images

Integrates images

Differences images

Has a local control panel

8080 micro processor for control and processing

Three graphics overlays

Cost $54,500.

Of the frame buffers available, the Quantex DS-50 appears to be a good choice. It has most of the directly implemented processing features, and can be interfaced to a standard bus system.

Video Disc Recorder

The video disk recorder records the integrated video data in analog form and allows immediate rapid review of integrated images after a mission. In addition, in the case of rapidly rotating objects it can record the direct video data, along with the video tape recorder.

One video disk system vendor has been connected: Eigen. The Eigen disk systems use a crash proof flexible disc. The following systems are available.

Model 16-05. Recording rates from single image up to 10 per second. 500 images can be stored.

Model 16-10. Recording and playback rates from single up to 30 frames per second. 300 images can be stored. GSA cost - $15,300.

Model 16-20. Recording and playback rates from single up to 30 frames per second. 600 images can be stored. GSA cost - $23,400.

Video Tape Recorder

The video tape recorder records the raw video data for later playback. In some cases the played back video may be used as the input to the system. This would occur in those cases where the integration time of the integrating frame buffer needs to be varied to optimize the image quality. Thus, the video tape recorder needs to be of high quality, capable of maintaining the

resolution present in the original video. Assuming the data would be digitized in a 653 x 490 format (utilizing all 490 active lines and maintaining a 4:3 aspect ratio) the number of pixels would be about 320,000. At a frame rate of 30 per second this corresponds to a pixel rate of 9.6×10^6 per second. The required bandpass would be one half of this or 4.8 mhz. Thus, a frequency response flat to about 5 mhz would be required to reproduce the data at a resolution consistent with the line sampling of the TV system. In actuality less bandwidth would probably be required, since, depending on focal lengths, the diffraction cutoff of the lens would possibly limit the maximum image frequency to a value less than this.

There are a variety of video tape recorders available ranging from expensive braodcast quality recorders to inexpensive industrial recorders. A fairly inexpensive video tape recorder which potentially would do the job is the RCA TC3350. This unit has a bandwidth of 5 mhz. Cost is $3585.

Real Time Digital Filter

The real time digital filter allows enhancement processing to be done on video data either during recording or playback modes. The filter digitizes the video, performs digital filtering in the spatial domain and converts the result back to an analog video signal. The filter is made by Quantex. Its characteristics are listed below.

DF-80 digital video filter.

Two dimensional filtering, 3 x 3 to 15 x 15 kernel sizes

Provides high pass filtering

Compensates for shading

Dynamic log function

Cost - $22,000.

Hard Copy Camera

There are a variety of video hard copy cameras available with different levels of sophistication. A camera which represents a very sophisticated and expensive approach is the Matrix 4000.

Color capability

512 x 512 resolution

Variable format - 1, 2, 4, 6, 9, 16, or 25 images on 8 x 10 Polaroid prints or transparencies

RS232 control

35mm camera

Polaroid processing kit

Total cost - $ 19,900.

Dunn Instruments makes a similar camera. A more modest camera system is the Video print made by Image Resource Corporation:

Color capability

256 x 256 resolution

RS 232 control

SX-70 Polaroid

35mm camera

desk top size

Total cost - approximately $ 7270.

Tektronix has several hard copy units. The 4634 would be the likely choice. Its characteristics are:

Black and white.

6 x 8 on specially treated paper.

One image per 12 seconds throughput rate.

Exposure to final print time is 26 seconds.

Cost: $8400.

Others undoubtedly exist. For the present the Tektronix system will be assumed to be adequate.

Control and Disk Storage System

The control and disk storage system has four main functions: transferring the digitized video data from the integrating frame buffers to a disc storage system, reversing the process during image playback, providing control signals to the various units in the total system, and transferring data from disk to the main CIS computer.

For the conceptual design a small Data General computer, the Eclipse S/140, was chosen to perform these tasks. This choice was made basically for compatibility with the Data General computer used for the CIS executive computer, the Eclipse S230. The compatability areas are: software, hardware, maintenance and interface.

Local representatives of Data General were contacted and the specifications were explained to them. After some analysis they felt confident that they could meet the specified throughput rate. A block diagram of their proposed system is shown in Figure 6.

The video from the integrating frame buffers would be connected to the computer high speed I/O bus via a special interface which would have to be designed and constructed. The Data General sales representative contacted a firm which has done this sort of work. An estimate of $15,000 for this task, including software, was given (letter in Appendix). The special interface is then connected to the Data General data channel and would have DMA access to the computer memory. The data is read out of memory onto disk using a burst multiplexer channel. This allows simultaneous reading of data into the memory from the frame buffers and writing to disk. This would be done in a ping pong fashion.

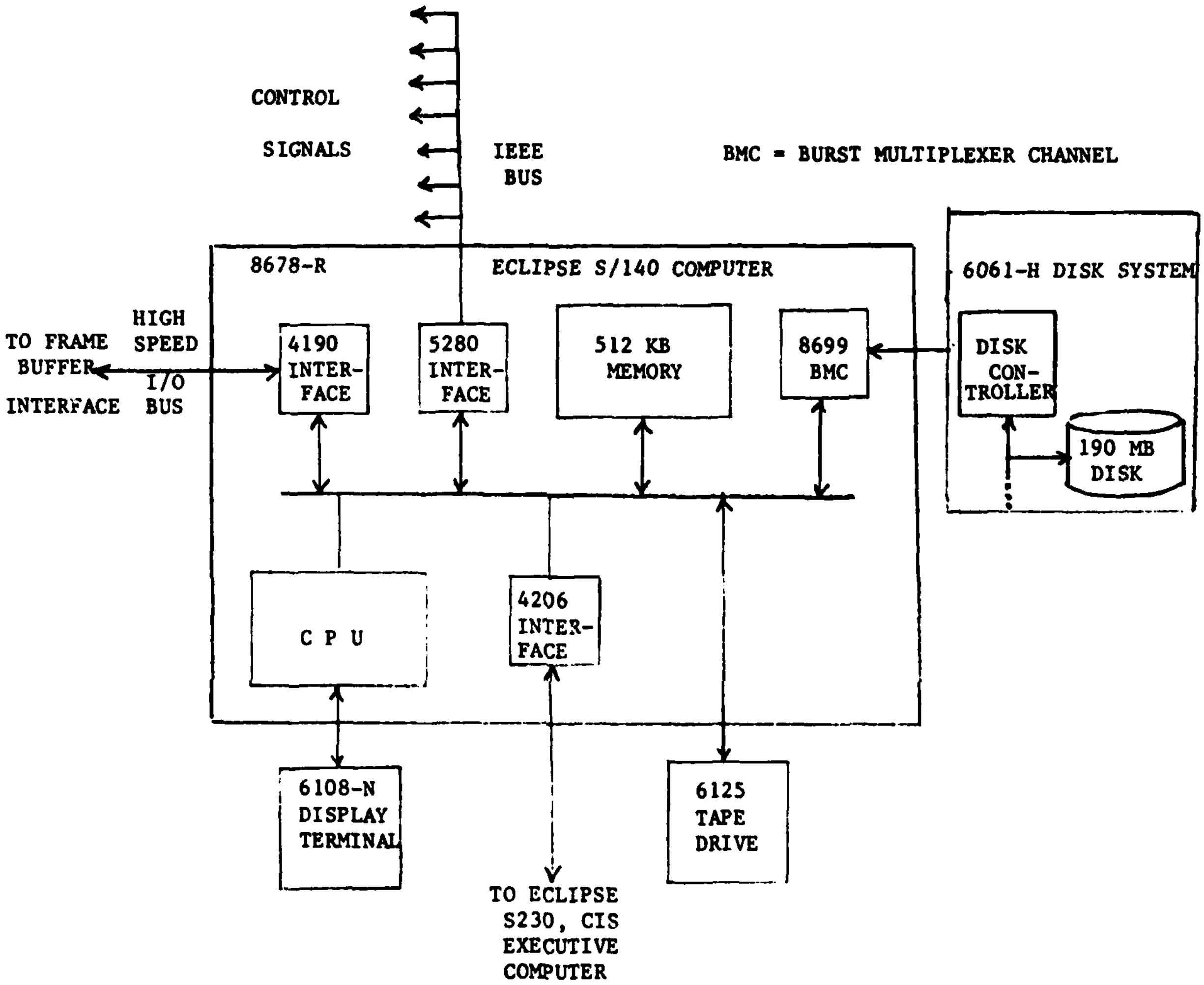


FIGURE 6. CONTROL AND DATA STORAGE SYSTEM.

A CCD camera, if available, would also be connected to the high speed I/O bus as would the present SEVS camera, if used. Interface hardware would probably be needed.

The system has an IEEE bus for providing control signals to the frame buffers, the video disk, video switching devices, and possibly to the date and time inserter.

The system has a standard Data General interface for connection to the CIS executive computer. This would allow data to be transferred back and forth between the two computers.

A tape unit is included for storing data on tape. This is a 45IPS, 1600 BPI tape drive, designed to operate mainly in a streaming mode.

The disk system holds 190 megabytes of data, so that the specification of storing 600 images is met. The disk is removable so that between passes a new disk could be put on.

An interface is available which would allow either the S/140 or S/230 computers to communicate with the disk drive.

A formal quotation was obtained from Data General (see Appendix). Costs are:

Data General Hardware -	$73,244.50
Data General Software -	1,784.75
	$75,029.25

The S/140 computer in txis case is probably more powerful than needed. The S/120 is probably better matched to the task but does not presently have the burst multiplexer feature. The Data General people said that this feature will be added in the near future to the S/120. This will result in a cost reduction.

Development of computer programs will be required to make the system work. The programming will be sophisticated in order to get the required throughput rate, but the number of processes to be programmed is relatively small. An estimate of six man months for programming all functions of the system is the present off-the-wall estimate.

COSTS

Materials

Camera (maximum)		47,000.
Integrating frame buffers, 2	$29,500.	59,000.
Video disk recorder		24,000.
Video Tape Recorder		3,585.
Real time digital filter		22,000.
Data and time inserter		5,000.
Computer and peripherals		73,244.
Hard copy system		8,400.
TV Monitors, 2 CONRAC 14 inch	1,140.	2,280.
Miscellaneous hardware		5,000.
Special interface for frame buffers		15,000.
		264,509.
	Tax	15,870.
		280,379.

Labor

Based on University of California pay scale and overhead rates.

Senior Development Engineer. 8 months

Principal Electronics Technician, 6 months

Programmer, 6 months

$155.000.

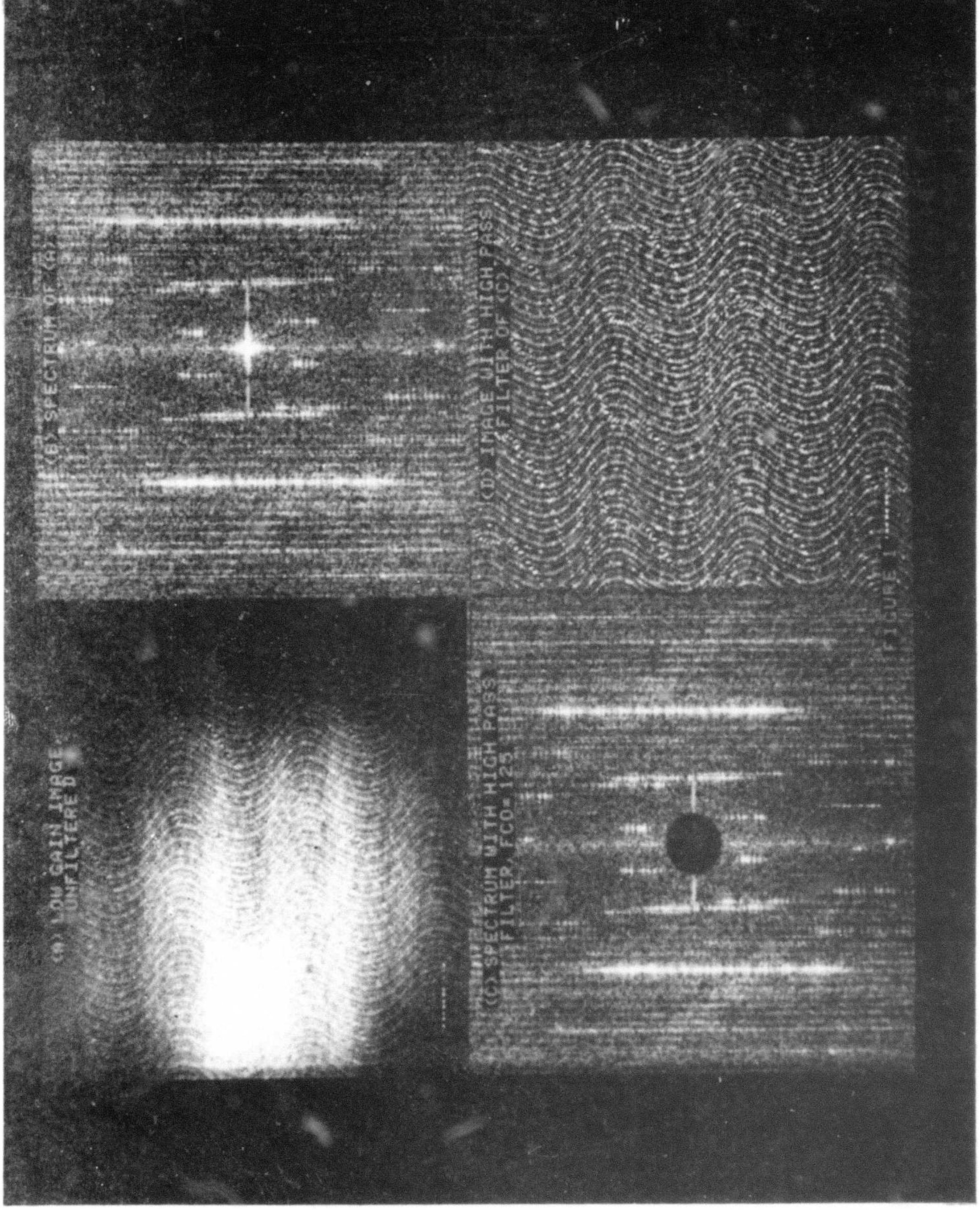
Total Cost

Materials	280,379.
Labor	155,000.
	$435,379.

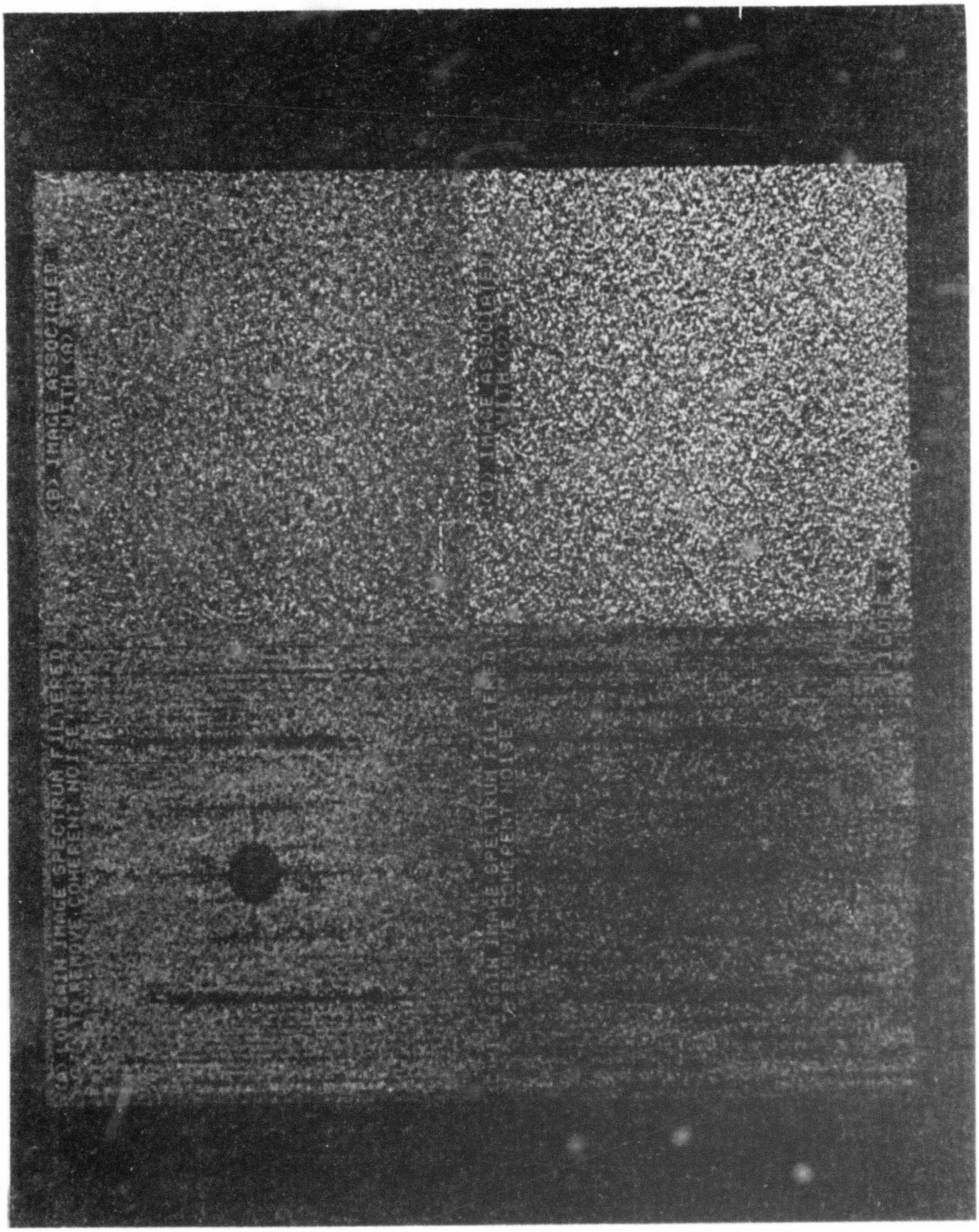
APPENDIX A

LETTER REPORT OF SEVS NOISE STUDY

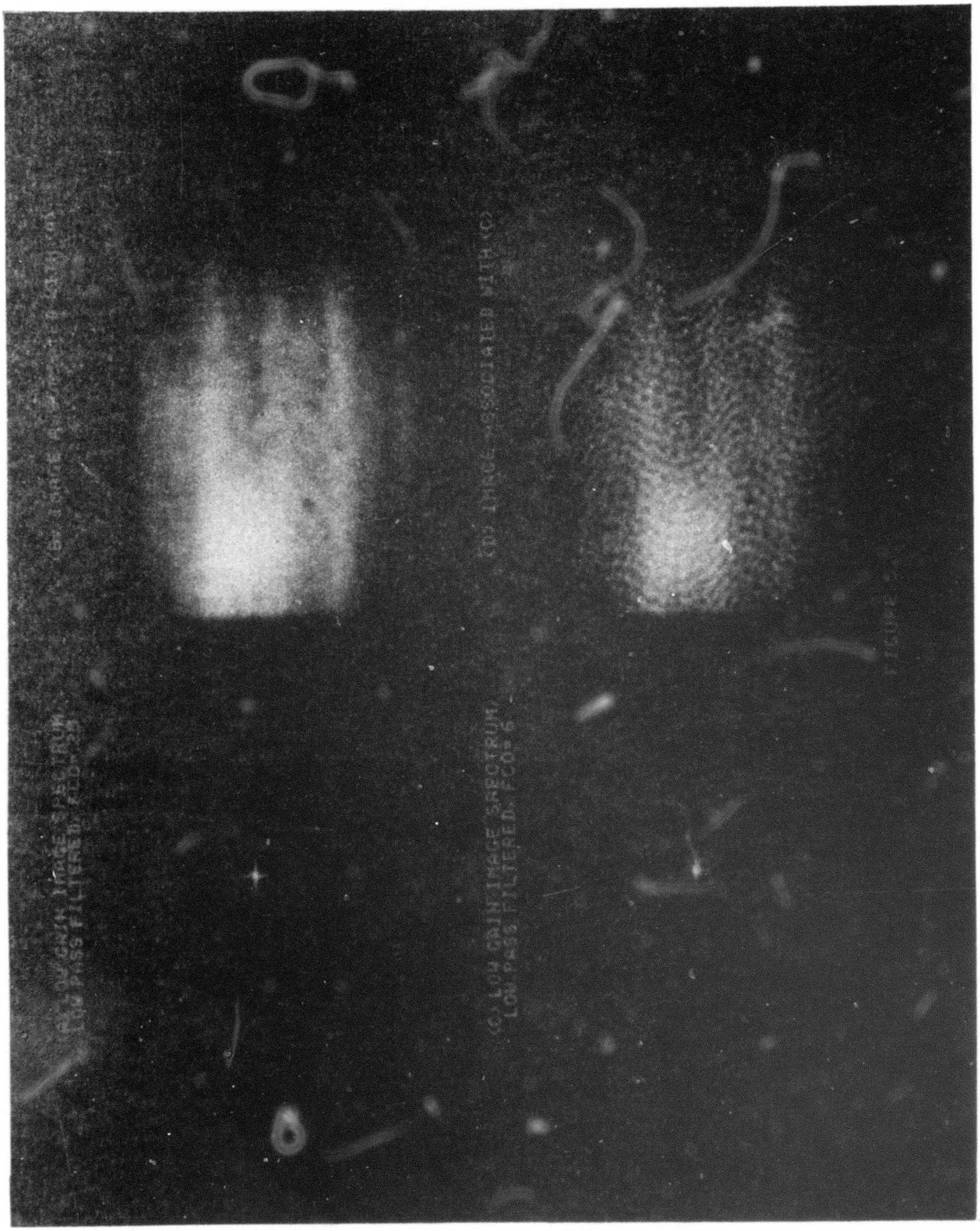
1


(A) LOW GAIN IMAGE
UNFILTERED
(B) SPECTRUM OF (A)
(C) SPECTRUM WITH HIGH PASS
FILTER FCO=125
(D) IMAGE WITH HIGH PASS
FILTER OF (C)
FIGURE 1

2



3


(C) LOW GRAIN IMAGE SPECTRUM,
LOW PASS FILTERED, FCO=6
(D) IMAGE ASSOCIATED WITH (C)